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(54) **AFTERBURNING AEROSPIKE ROCKET NOZZLE**

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(51) **Int. Cl.**[7] **F02K 1/04**
(52) **U.S. Cl.** **60/770**; 60/761; 239/265.17
(58) **Field of Search** 60/770, 246, 39.63, 60/761; 239/265.17

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(57) **ABSTRACT**

An aerospike nozzle includes a nozzle body and a spike, the nozzle body and the spike defining a generally annular gas flow channel therebetween; the spike comprising an upper, generally conical section having a decreasing diameter in a downstream direction; a middle, generally cylindrical section having a generally constant diameter; and a lower, generally conical section having a decreasing diameter in a downstream direction; a shroud disposed radially outward of the spike and longitudinally downstream of the nozzle body, the shroud comprising a first generally cylindrical section and, downstream of the first section, a second generally concave section; a plurality of struts connected between the spike and the shroud; an ambient air inlet defined between the nozzle body and the shroud; a mixing and combustion chamber defined between the spike and the first section of the shroud; and an expansion chamber defined between the spike and the second section of the shroud.

6 Claims, 2 Drawing Sheets

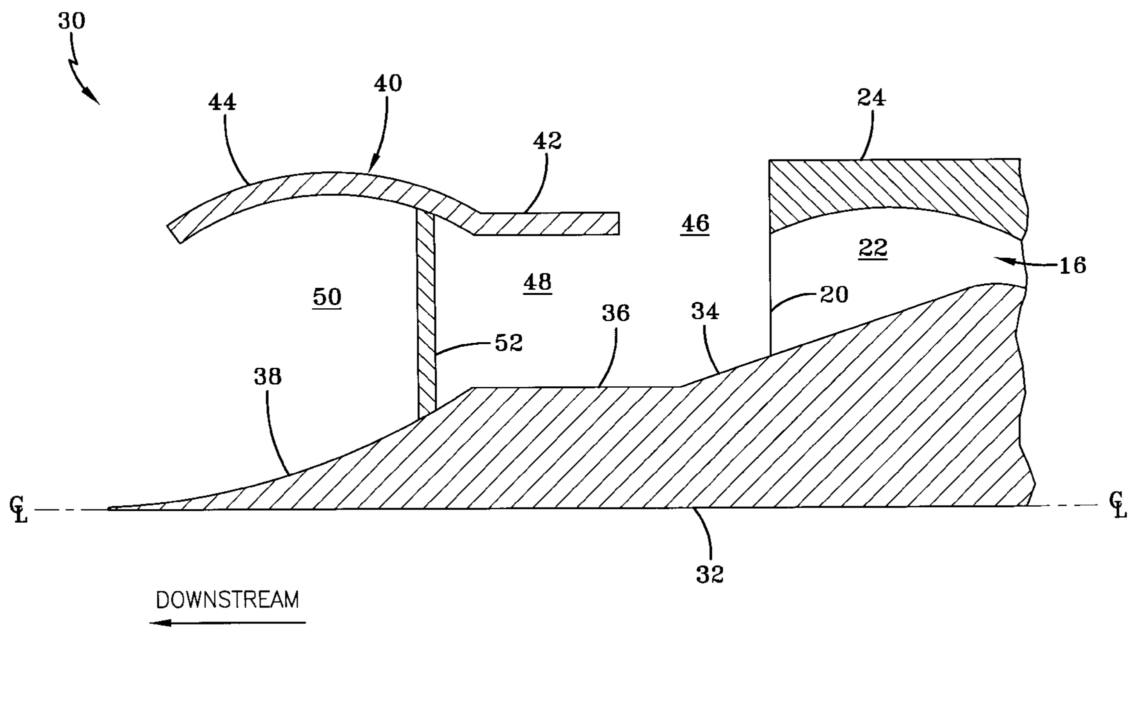
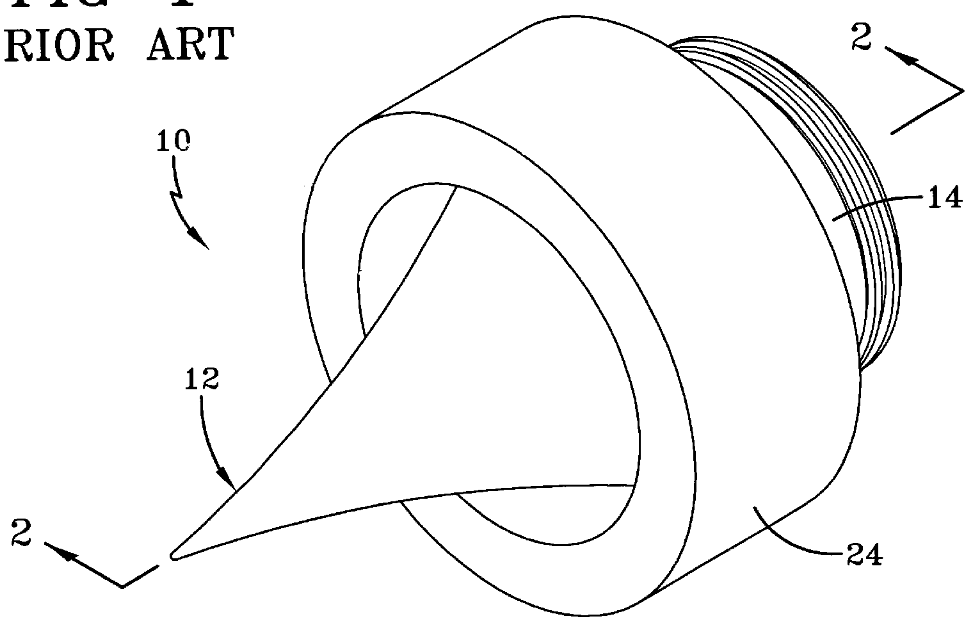


FIG-1
PRIOR ART



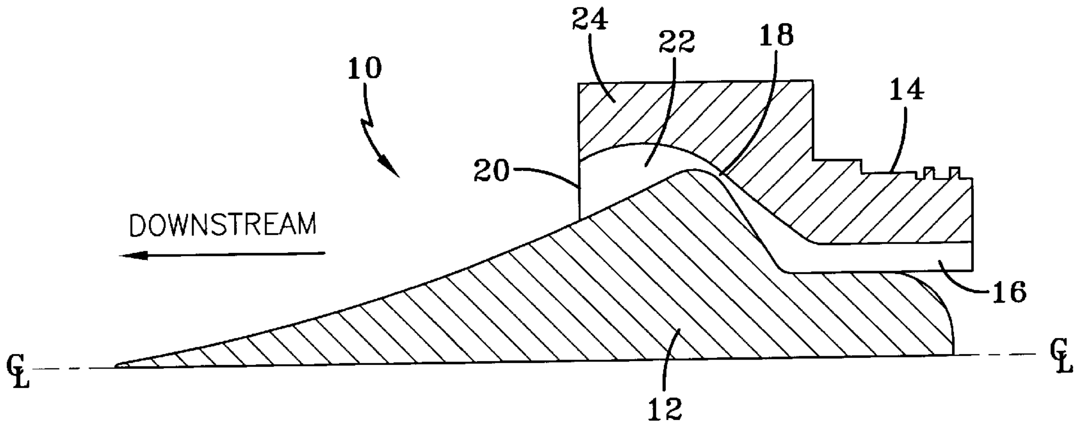


FIG-2
PRIOR ART

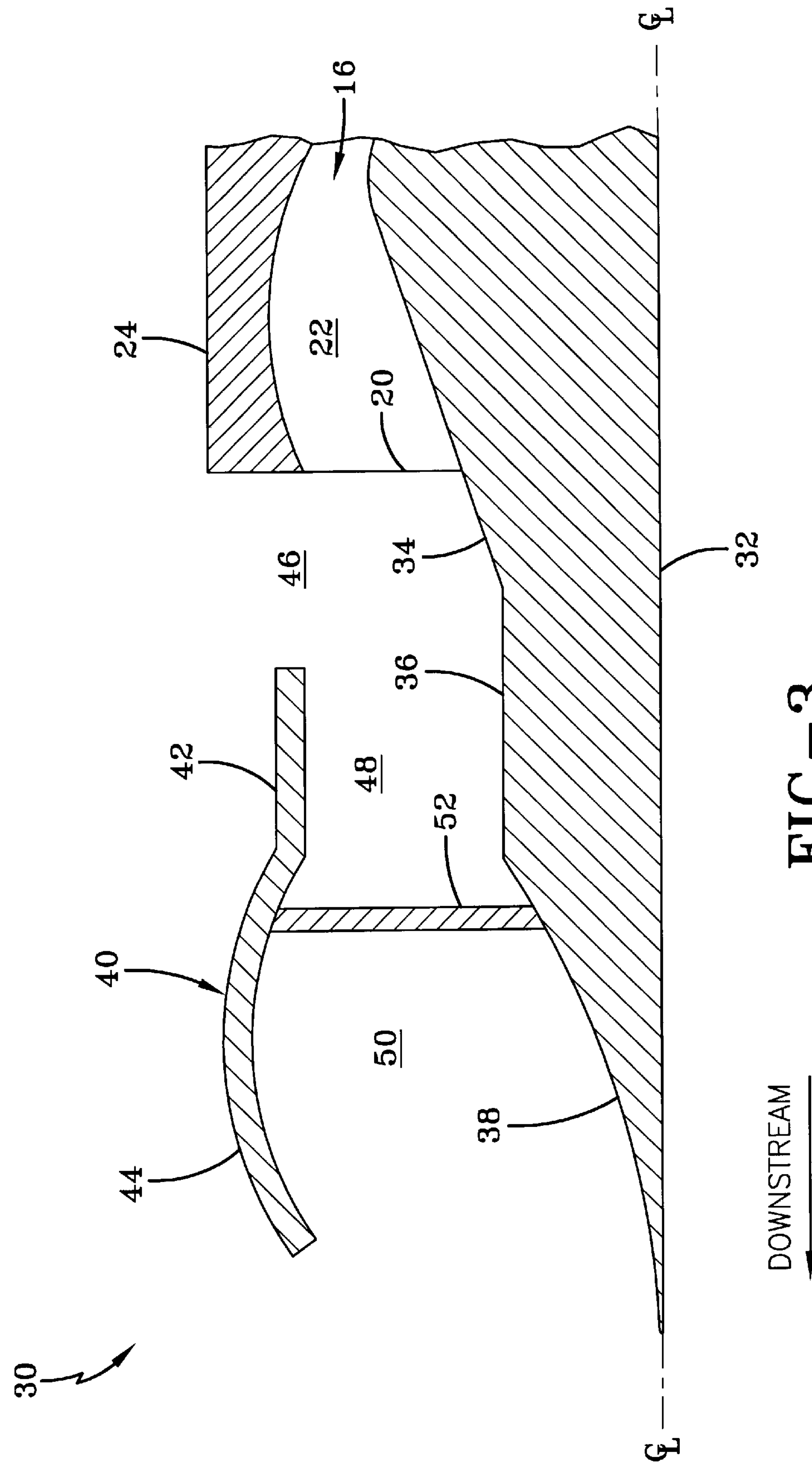


FIG-3

AFTERBURNING AEROSPIKE ROCKET NOZZLE

STATEMENT OF GOVERNMENT INTEREST

The invention described herein may be manufactured and used by or for the Government of the United States of America for government purposes without the payment of any royalties therefor.

BACKGROUND OF THE INVENTION

The invention relates in general to aerospike rocket nozzles and in particular to afterburning aerospike rocket nozzles.

Rocket motors are limited in their performance by the energy content of their propellants and the need to carry their oxidizer with them. Rocket motors do, however, provide near-instantaneous thrust and are not limited to atmospheric operation. Jet engines use air to provide their oxidizer, but are either inherently complex (e.g., turbojets and turbofans) or provide no thrust at zero initial speed (ramjets). Because of their use of atmospheric oxygen, jet engines cannot operate in space and take a considerable period of time to "spool-up" to full thrust. Jet engines also tend to need substantial levels of maintenance and are quite costly to acquire, maintain and operate. Rocket motors (particularly solid fuel rocket motors) tend to be relatively inexpensive to acquire, require minimal maintenance and virtually nothing to operate.

To try to improve the delivered energy of rocket motors, many methods have been employed. The energy of the fuels and oxidizers have been increased, the nozzles have been contoured and modified to improve their efficiency and the operating pressures have been increased. However, the delivered propellant specific impulse (a measure of the thrust produced per unit mass of propellant) has not appreciably changed since the 1950's. Another approach has been to use so-called "ducted rockets," which bring air into the combustion chamber via inlets and flow ducts, where the air combines with the propellant gases to increase the specific impulse of the propellant. While ducted rockets have been investigated since at least the mid 1960's, they have never progressed beyond the prototyping stage because of their inherent difficulties and complexity. In particular, bringing air into the combustion chamber uses much available volume which could otherwise be used for propellant and subjects the duct materials to extremely harsh thermal and flow conditions. To date, no one has been able to overcome these problems with sufficient success to justify the increased cost and complexity.

The present invention, an afterburning aerospike nozzle, improves the delivered energy density of rocket motors, with less complexity than ducted rocket motors.

The invention will be better understood, and further objects, features, and advantages thereof will become more apparent from the following description of the preferred embodiments, taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings, which are not necessarily to scale, like or corresponding parts are denoted by like or corresponding reference numerals.

FIG. **1** is a perspective view of a known aerospike nozzle.

FIG. **2** is a cross section along the line **2**—**2** of FIG. **1**.

FIG. **3** is a partial cross section of an aerospike nozzle according to the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. **1** is a perspective view of a known aerospike nozzle **10**. FIG. **2** is a cross section along the line **2**—**2** of FIG. **1**. In FIG. **2**, the lower half of the cross-section below the centerline is not shown, but is a mirror image of the upper half.

Aerospike nozzle **10** includes nozzle body **24** and spike **12** which define therebetween a combustion gas flow channel **16**. The combustion gas flows in to the flow channel **16** from the rocket motor (not shown) on the right side of the drawing in FIG. **2**. The gas flows in the direction indicated by the DOWNSTREAM arrow in FIG. **2**. Nozzle body **24** includes portion **14** for attachment to the rocket motor case.

The combustion gases are forced through a narrow annulus that forms the throat **18** of the flow channel **16**. The gas first expands in expansion area **22** where it exerts pressure on both the nozzle body **24** and spike **12**. The flow channel **16** ends at exit **20**. The gas then exerts pressure against the spike **12** until it leaves the nozzle **10** completely. The thrust of the nozzle is produced by the pressure acting on the internal expansion area **22** of the nozzle body **24** along with the pressure acting on the spike **12**.

While the expanding gases are higher in pressure than the local atmospheric pressure as they leave the expansion area **22**, the exhaust can never be overexpanded. Overexpanded means that the pressure in the gas leaving the exit **20** is lower than that in the atmosphere it enters. This situation would result in a net loss of thrust from the nozzle. The spike **12** functions to recover a portion of the energy that would otherwise be lost from exhausting underexpanded gases above the design altitude of the inner nozzle. Often, the gas leaving exit **20** is fuel rich, that is, it contains unburned fuel. The present invention described below helps to utilize any unburned fuel.

FIG. **3** is a partial cross section of an aerospike nozzle **30** according to the invention. That portion of nozzle **30** to the right of (upstream of) exit **20** is the same as shown in FIG. **2** and is not shown in FIG. **3**.

As shown in FIG. **3**, the aerospike nozzle **30** includes a nozzle body **24** and a spike **32**. The nozzle body **24** and spike **32** define a generally annular gas flow channel **16** therebetween. The spike **32** includes an upper, generally conical section **34** having a decreasing diameter in a downstream direction; a middle, generally cylindrical section **36** having a generally constant diameter; and a lower, generally conical section **38** having a decreasing diameter in a downstream direction.

Nozzle **30** further includes a shroud **40** disposed radially outward of the spike **32** and longitudinally downstream of the nozzle body **24**. The shroud **40** includes a first generally cylindrical section **42** and, downstream of the first section **42**, a second generally concave section **44**. Strut **52** connects shroud **40** to spike **32**. While one strut **52** is shown in FIG. **3**, it should be understood that a plurality of struts **52** are disposed radially around spike **32** to connect shroud **40** to the spike. The number, configuration and exact location of the struts **52** may vary, depending on thermal, ballistic and structural requirements.

An ambient air inlet **46** is defined between the nozzle body **24** and the shroud **40**. A mixing and combustion chamber **48** is defined between the spike **32** and the first section **42** of the shroud **40**. An expansion chamber **50** is defined between the spike **32** and the second section **44** of the shroud **40**.

In a preferred embodiment, the first section **42** of the shroud **40** is disposed radially outward from the middle section **36** of the spike **32** and the second section **44** of the shroud **40** is disposed radially outward from the lower section **38** of the spike **32**.

In one embodiment, each strut **52** is connected at one end to the lower section **38** of the spike **32** and at another end to the second section **44** of the shroud **40**. In another embodiment, each strut **52** is connected at one end to the middle section **36** of the spike **32** and at another end to the first section **42** of the shroud **40**. The lower section **38** of the spike **32** may define a generally concave outer surface.

The aerospike nozzle **30** operates as follows. The fuel rich (oxidizer poor) propellant gases exhaust from exit **20**. The flow of the propellant gases entrains ambient air through the ambient air inlet **46** (via viscous forces), much as the aspirator commonly used in laboratories draws air from a desiccator. The ambient air and propellant gases are then forced to combine in the mixing and combustion chamber **48**. The combined ambient air and propellant gases then expand out over the lower section **38** of the spike and the second section **44** of the shroud to produce the final thrust. The lower section **38** of the spike serves both as a means to extract the energy from the high pressure gases and as a flame holder.

The relative dimensions of the components may be modified to optimize the fuel-air ratio. For instance, if more air is required, the ambient air inlet **46** can be made larger than the exit **20** to catch "ram air" from the area next to the rocket motor while it is in high speed flight. The components of the invention can all be fabricated from conventional nozzle materials without extending the state of the art beyond that required by the nozzle itself.

The volume used by the mixing and combustion or afterburning chamber **48** on aerospike nozzle **30** is the same region that would be used by the expansion cone on a conventional nozzle. Therefore, the additional impulse is obtained without increasing the size of the rocket motor. Calculations suggest that increases of 50% to 100% in propellant specific impulse are achievable using the present invention. While there is some increase in drag created by adding the ambient air inlet **46**, it may be no greater than that created by the inherent recirculation region around a conventional exit cone. The increase in specific impulse results in greater range and greater velocity.

Use of aerospike nozzle **30** introduces the opportunity for varying the thrust of the rocket motor by moving the spike **32** into or out of the nozzle body **24**. This simple expedient varies the flow area at the throat of the nozzle. Changing the throat area changes the internal pressure of the rocket motor which changes the burning rate of the propellant. This means that one can achieve high thrusts or lower thrusts as needed for a mission profile. That capability will allow a solid propellant rocket motor to be used in place of more expensive liquid rocket motors where variable thrust is a requirement.

The aerospike nozzle **30** can also produce a vectored (directed) thrust by moving the spike **32** and/or the nozzle body **24** to one side or canted relative to the center line of the rocket motor. Therefore, the direction of flight can be controlled without fins or other complex (e.g., gimbaled nozzle) or energy absorbing (e.g., jet tabs) mechanisms. Also, less energy is lost to these directional mechanisms.

Roll control (where required) can be achieved in the nozzle by using "jet vanes." The jet vanes can be put in either the initial propellant gas flow or in the final exit gases. In both cases, they can be smaller than in traditional nozzles because they are far from the centerline of the rocket motor and in relatively dense gas moving at high speeds. Therefore, they provide unusually large amounts of torque per unit area of vane. When they are in the final exit gases, they can be made using less exotic materials (e.g., steel vs. tungsten) because the flow is much cooler than in conventional rocket nozzles. The aerospike nozzle is more tolerant of flow disruptions because of these vectoring operations than is a conventional nozzle, because of its basic method of operation. This means that energy losses in the nozzle will be less than in a conventional nozzle.

A number of other alternative configurations are possible. For instance, a truncated aerospike can be used. In a truncated aerospike, the spike is shortened, leaving a flat face. The truncated variant will be lighter and shorter. Studies have shown that this configuration in prior aerospike nozzles suffers very minor loses in thrust.

While the invention has been described with reference to certain preferred embodiments, numerous changes, alterations and modifications to the described embodiments are possible without departing from the spirit and scope of the invention as defined in the appended claims, and equivalents thereof.

What is claimed is:

1. An aerospike nozzle, comprising:

a nozzle body and a spike, the nozzle body and the spike defining a generally annular gas flow channel therebetween;

the spike comprising an upper, generally conical section having a decreasing diameter in a downstream direction; a middle, generally cylindrical section having a generally constant diameter; and a lower, generally conical section having a decreasing diameter in a downstream direction;

a shroud disposed radially outward of the spike and longitudinally downstream of the nozzle body, the shroud comprising a first generally cylindrical section and, downstream of the first section, a second generally concave section;

a plurality of struts connected between the spike and the shroud;

an ambient air inlet defined between the nozzle body and the shroud;

a mixing and combustion chamber defined between the spike and the first section of the shroud; and

an expansion chamber defined between the spike and the second section of the shroud.

2. The aerospike nozzle of claim **1** wherein the first section of the shroud is disposed radially outward from the middle section of the spike.

3. The aerospike nozzle of claim **2** wherein the second section of the shroud is disposed radially outward from the lower section of the spike.

4. The aerospike nozzle of claim **1** wherein each strut is connected at one end to the lower section of the spike and at another end to the second section of the shroud.

5. The aerospike nozzle of claim **1** wherein each strut is connected at one end to the middle section of the spike and at another end to the first section of the shroud.

6. The aerospike nozzle of claim **1** wherein the lower section of the spike defines a generally concave outer surface.

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